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NEW TECHNIQUES IN THE PROCESSING OF VEGETABLE OILS AND FATS OF SPECIAL INTEREST FOR TROPICAL AREAS

By Ben BRAAE,
Licentiate in Technology

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No.1762 New Techniques in the Processing of Vegetable Oils and Fats of Special Interest for Tropical Areas

D.5.4./D.5.5.

by Ben Braae, Licentiate in Technology

Several kinds of oliferous plants are indigenous to tropical areas. The fruits of these plants contain considerable amounts of vegetable oils or fats which can be used not only for edible purposes but also for many technical applications, for instance, as raw material for the manufacture of soap. Typical examples of such fats are coconut oil, palm oil, palm kernel oil and groundnut oil and there are many others.

(a) Recovery of Oil or Fats from Natural Oliferous Material

Obviously the methods used for recovering oil or fat from the fruit of oliferous plants will depend on the kind of the fruit, its size, the thickness and the mechanical characteristics of the shell as well as on the oil content of the raw material, and the kind of non-fatty material from which the fat has to be extracted.

In the case of coconut oil, the shell of the nut is first opened by hand or by a special machine and the fruit meat then dried over open fire or in specially constructed ovens. This gives a product called copra which with a low water content and good keeping qualities can easily be stored and transported. The low water content is of great importance because all fats are subject to hydrolysis when water is present, thus forming free fatty acids, which may influence the suitability of the fat for nutritional purposes, and which in any case will give rise to big losses during the refining operations necessary to produce an edible oil of good quality.

The oil is recovered from the copra by mechanical pressing or by solvent extraction or by a combination of both methods. For many years hydraulic presses were used for the recovery of the oil, but these presses leave a relatively great amount of oil in the cake, and require a great amount of manual labour. Modern screw presses or expellers have a higher power consumption, but need less labour and leave less than 4 per cent of oil in the cake. A method which nowadays has achieved widespread application is the recovery of the oil from the cake by means of solvent extraction. A hydrocarbon, usually hexane, is used for this purpose and the yield of oil is very high. The oil content of the cake is always lower than one per cent and in many types of extraction plants is considerably lower. However, solvent extraction plants are relatively expensive as distillation equipment for the recovery of the solvent must be included and as special precautions must be taken in order to avoid losses of expensive solvent as well as the risk of fire.

Depending on the type of raw material as well as on the cost of electric power, steam, etc. it is often a sound economic proposition to combine the mechanical expelling method for the recovery of the fat with the solvent extraction method. As the yield of oil obtained by expeller per hour, it is obvious that a high yield of oil can only be obtained at a high investment cost and a high power consumption per unit of oil produced. However, if the throughput of the meat through the expeller presses is increased the unit cost per ton of oil is considerably reduced, even if the yield of oil is also reduced. On the other hand, many types of solvent extraction plants

do give the most economic results, and the highest oil yields, when the amount of oil contained in the meat is not too great. Thus the optimal economic result is often obtained by a combination of mechanical expelling and solvent extraction of the seeds.

Special treatment of the oil seeds such as milling, rolling, etc. is necessary in order to obtain high oil yields, but these treatments will vary with the kind of seed and cannot therefore be discussed in detail. For the recovery of oil from palm kernels and groundnuts methods very similar to those described for the recovery of oil from copra are used. The oil cakes from the expeller presses as well as the meat from the solvent extraction plants have a considerable value as cattle fodder. It has been found that the nutritional value of the cakes depends mainly on the protein content and hardly on the amount of fat remaining in the cakes. From an economic point of view it is therefore of advantage to leave as little fat as possible in the cakes.

In the case of palm oil a somewhat different treatment must be applied due to the different characteristics of the raw material. The red palm oil is contained in the fruit meat surrounding the kernels of the fruit of the palm tree. This fruit meat is boiled in water, often autoclaved at a temperature above 100°C (212°F), thus liberating the oil from the fruit meat. The bulk of the fruit meat is then removed by screening and by special centrifuges capable of removing solid matter from the suspension of oil in water. The oil and the water are then separated by means of specially constructed centrifuges, leaving a minimum of oil in the drabwater. The oil thus obtained will usually still need another centrifugal purification in order to remove the last traces of water and impurities.

The fruit meat of the palm fruit contains a lipolytic enzyme which provokes a very rapid hydrolysis of the palm oil. It is therefore of the utmost importance that the autoclevation of the fruit meat is carried out as soon as possible after the fruit is gathered if serious deterioration ot the palm oil is to be avoided.

(b) Alkali Refining of Vegetable Oils

In some countries crude vegetable oils, produced as described above are used directly for human consumption. However, modern requirements regarding keeping qualities and organoleptic properties of the oil necessitate that these crude oils be subjected to a number of chemical treatments. The first of these treatments is the alkali refining.

The alkali refining of fatty oils aims at the removal of constituents other than glycerides, such as free fatty acids, phospahatides and pigments, which render the unrefined oils more or less unfit for human consumption and unsiutable for technical purposes.

Of all known methods of refining treating the oil with caustic soda is that most generally used, the reason being that not only the fatty acids but also other substances which must be removed to produce an oil of adequate quality are attacked by the lye.

Traditionally the alkali refining of fatty oils has been by the batch method in big tanks containing from 5 to 50 tons of oil. However, considerable losses of neutral oil are involved by this

method. Due to the long contact time between oil and lye (usually between 15 and 30 minutes) inherent in the batch process any excess of lye necessary to remove gums and coloured matter is almost entirely consumed in the saponification of neutral oil.

In the continuous refining process the contact time between oil and lye may be reduced to a few seconds, the losses of neutral oil being correspondingly reduced.

Centrifugal separators have made it possible to cange over from batch to continuous processing in the refining of fatty oils. Caustic soda is continuously mixed with the oil, the free fatty acids as well as other impurities reacting with the alkali forming a by-product known as soapstock. In modern continuous plants the ratio between oil and caustic soda is kept constant and independent of the oil flow. In the centrifuge the oil is continuously separated from by-products, such as soapstock, wash water, etc. (See Figure I).

In all types of continuously operating separator bowls it is necessary to adapt the position of the boundary zone between the two phases with reference to the difference in their specific gravities. When using conventional "open type" separators this is effected by interchangeable regulating disks, past which the heavy component leaves the bowl. However, the regulating disks cannot be changed during operation as the bowl must be stopped every time it is desired to alter the boundary zone. In modern separators of the hermetic type the position of the boundary zone and thus the separation result can be altered while the separator is in operation by using a throttle valve to vary the back pressure in the outlet line. (See Figure II).

In a hermetic separator the mixture of oil and soapstock is introduced to the bowl under pressure through the hollow rotating separator spindle. This constitutes a very mild treatment of the reacting material and reduces the risk of particle break-up and emulsification. Both the inlet and the outlet of the hermetic separator are fitted with axial seals, which prevent the oil from coming into contact with air.

Modern continuous refining processes comprise a treatment with citric or better still phosphoric acid prior to neutralisation. These acids attack phospahatides present in the oil, reduces the tendency for emulsification (thus reducing the losses), and improves the organoleptic properties of the oil. The acids are neutralised together with the free fatty acids.

Some oils, but not those mentioned here, may need further alkali treatment in order to improve the colour and the quality.

The neutralised oil is finally washed with hot water in order to remove the last traces of soap and the oil is finally dried in vacuum.

When using hermetic separators the continuous refining plant is in fact a completely closed system, where the oil has no contact whatsoever with the air from the moment the crude oil is pumped into the plant until the refined and dry oil leaves the drying section. Consequently no oxidation of the oil takes place during the refining operation, and a refined oil having excellent organoleptic properties as well as a high stability during storage is obtained.

The reason why the conventional batch refining plants nowadays are being rapidly replaced by continuous plants may be summarised as follows:

(i) The continuous refining plant is extremely easy to operate and takes up very little space. The somewhat higher capital cost of a continuous plant as compared with batch plants is offset by a corresponding reduction in building costs. Running costs and maintenance expenses for the continuous plants are low.

(ii) Continuous refining plants are extremely flexible and the same plant can be used for refining all kinds of fatty oils with the exeption of castor oil.

(iii) Due to the short reaction time between oil and lye and to the efficient separation of the oil from the by-products obtained when using separators, especially of the hermetic type, refining losses are very low. Thus the initial investment cost of a continuous plant is very quickly recovered.

(iv) There is a considerable improvement in the quality of the refined oil as compared with that produced by older refining methods, due partly to the phosphoric acid treatment which completely removes all traces of phosphatides, and partly to the hermetically closed refining system which completely prevents any deterioration of the oil by oxidation. With alkali refining of fatty oils a by-product called soapstock is obtained. The soapstock contains the sodium salts of the free fatty acids contained in the crude oil as well as water and certain minor impurities, mainly gums. The soapstock obtained when refining the kind of oils dealt with here, is of relatively good quality, because the amount of impurities and especially coloured material is relatively low. Consequently the soapstock may be used directly as a raw material for soap-making, especially if it is a question of producing only laundry soap or industrial soaps.

However, if high-grade toilet soap is required, it is necessary to purify the soapstock. In such cases the soapstock is treated with sulphuric acid and a product called "acid oil" is obtained; this consists mainly of fatty acids containing some neutral oil. The acid oil is practically water-free and the transport costs involved with this product are consequently lower than for soapstock, a fact which is of great importance. However, the acid oil is still not pure enough to be used as a raw material for high-grade toilet soaps and is therefore usually further purified by means of vacuum distillation. In this way distilled fatty acids, which fulfil high quality soap-making requirements, are obtained.

(c) Further Refining Treatments: Bleaching, Deodorisation, Winterising, Hardening

The alkali refined oils are still not suitable for human consumption, as they contain certain coloured substances as well as odiferous matter, which must be removed.

The alkali refining is therefore followed first by a bleaching

process and then by deodorisation. The purpose of the bleaching process is to remove coloured matter; this is done by mixing the oil with bleaching earth - preferably activated. The bleaching is usually carried out in batch containers, the bleaching earth being thoroughly mixed with the oil. The temperature is usually about 100°C (212°F) and the contact time approximately 20 - 30 minutes. The bleaching earth is then removed from the oil by filtration.

The oils mentioned here are relatively easy to bleach and only a small amount of bleaching earth, usually less than 0.5 per cent, is necessary. Palm oil is an exception as the red colour (carotenoids) is not easily removed by the treatment with bleaching earth. Higher temperatures and blowing with air is therefore sometimes used, but this treatment has a deleterious effect on the oil. Other oils, for instance cottonseed oil, have a much darker colour, and the amount of bleaching earth necessary is therefore much greater.

Even the bleached oils have a characteristic flavour which is objectionable in most cases if the oils are to be used for human consumption. This flavour is due to the presence of very small amounts of odiferous matter, which are removed by blowing steam through the oil. This process is known as deodorisation, a process which can be carried out both by the batch method and by continuously working equipment. The last-mentioned method is especially suitable if relatively great quantities of oil - say, approximately 50 tons a day - have to be treated. Continuous deodorisers effect a considerable saving of steam as compared to the batch deodorisation. The steam blowing is carried out at temperatures between 180°C - 220°C (356°F - 428°F), depending on the type of oil to be deodorised, the holding time, and the material of which the deodoriser is made. The lower temperature is mainly used in batch deodorisers constructed of ordinary mild steel, whereas the higher temperature is used in continuous deodorisers, having a much shorter holding time, and usually being constructed of stainless steel. The time of steam blowing, and thus the steam consumption, varies very much with the kind of oil to be deodorised. The oils mentioned here are relatively easy to deodorise but other oils, such as soyabeen oil and rape seed oil, need much more through treatment in order to give a satisfactory result.

When used as salad or cooking oil it is desirable that the oil keeps clear. Some oils, for instance cotton seed oil, sunflower seed oil and certain others, contain waxes which precipitate at room temperature. These waxes may be removed by a process known as winterising, by which the oil is cooled down to such a temperature where the waxes crystalise. They are then removed by filtration and a clear, brilliant oil is obtained. The melting point of a given fat is a characteristic which has an important bearing on the use of the fat in question for manufacturing marketable products. When making salad or cooking oil a fluid oil must be used. For the manufacturing of margarine or shortening fats with higher melting points must be chosen. Fortunately the oil technician has at his disposal a method to produce fats of any desirable melting point. This process is called hydrogenation or hardening. The startening material for this process is fluid oil, for instance groundnut oil, cotton seed oil, fish oil, etc. Such oils are reacted with hydrogen in the presence of a suitable catalyst. By this treatment the melting point of the oil is raised to any desired value. Due to the

fact that natural fats with high melting points, such as coconut oil, are in great demand, not only for human consumption but also as raw material for many industrial products such as soap, the hardening process gives the manufacturers of edible products such as margarin a big liberty in the choice of raw materials.

(d) Marketable Products in the Edible Oil Industry

For climatic and traditional reasons the human consumption of natural fats for centuries has been divided mainly in three different groups: butter, olive oil and lard. As the supply of these natural fats is not sufficient to satisfy the steadily increasing consumption, the modern edible oil industry has concentrated on manufacturing products which closely resemble the traditional ones, but which could be manufactured from more easily available raw materials.

Margarine is consequently produced as a substitute for butter, fluid oils such as groundnut oil, soya-bean oil, sunflower seed oil as a substitute for olive oil, and shortening as a substitute for lard.

When alkali refined, bleached and deodorised, possibly also winterised, fluid oils can be used as salad or cooking oil.

The manufacture of margarine is somewhat more complicated. Apart from flavour, keeping qualities, colour, etc., the most important property of margarine - as well as that of butter - is its plasticity or spreadability. These properties can only be obtained when fats of different melting points are used in the production of margarine. The fats used are refined as described above and a fat blend consisting of oils with different melting points is then prepared. The composition of the blend will depend on the climatic conditions in the country of consumption and on the type of margarine to be produced. Natural fluid oils are mixed in appropriate proportions with fats having higher melting points; these are often obtained by hardening of liquid fats.

The other main ingredient of margarine is skimmed milk, and there are the minor ingredients such as emulsifiers, vitamins, colouring matter, etc., which may also be added. These ingredients are throughly mixed at a temperature where all are liquid, usually approximately 50°C (122°F), and special emulsifying machines are used so that the skimmed milk forms small drops in the fat mixture. The emulsion is then rapidly cooled down on chilling drums or pressure coolers and the solidified mass packed.

It should be mentioned that margarine has a big sale, not only for direct human consumption, but also for the bakery industry.

The third main product manufactured for edible purposes from fatty oils is shortening. Shortening is pure fat with no water content and a relatively high melting point. As is the case with margarine, fats of different melting points are mixed together in order to obtain the desired plasticity. Shortening is used for frying purposes and is also widely used in the bakery industry, for instance in making biscuits.

(e) Soap-making

Some of the fats mentioned here are also important raw materials for soap-making. Marketable soaps can be divided into three groups:

high quality toilet soap, laundry soap, and industrial soaps. The quality requirements for the raw materials used to manufacture toilet soap are, of course, the highest, a mixture of tallow and coconut oil being the best, However, for coconut oil it is possible to substitute palm kernel oil, while to some extent palm oil can be substituted for tallow, especially if the amount of coconut oil is reduced.

For the other types of soaps many other fats as well as soapstock or fatty acids from soapstock may be used.

(i) Soap-making from Neutral Fats

A neutral fat is a chemical composition of fatty acids and glycerol. In the saponification process the fat is reacted with caustic soda, thus forming sodium salts of fatty acids (soap) and free glycerol. In conventional soap-making this process is carried out in batch, a tedious and time-consuming operation, because the saponification must be complete if the keeping quality of the finished soap is to be good.

As the glycerol is a very valuable by-product, the recovery of which is of great economic importance for a soap factory, the saponification operation is followed by a number of washings in brine. After each washing the spent lye is decanted from the soap and drawn off. The spent lye is then concentrated by distilling the water, the glycerol finally being distilled in a vacuum in order to obtain a high quality glycerol.

When making high grade toilet soap, the soapmass usually undergoes a fitting operation, where the mass is divided into neat soap and niger. The niger contains the bulk of impurities such as coloured material, oxy-fatty acids, etc., the presence of which is harmful to the quality of the soap. The neat soap, on the other hand, possesses the best possible physico-chemical properties for the further treatment of the soapmass. The niger and the neat soap is then decanted and the niger drawn off, while the neat soap is going for further treatment. When using the old batch process, this whole procedure may take an entire week, a considerable amount of capital thus being tied up during this time. Furthermore, the steam consumption for keeping the soapmass at the desired temperature throughout so long a period and the success of the operation depend very much on the personal skill of the soapboiler. With the batch process large amounts of scrap, which must be reworked, are easily formed.

In order to avoid these difficulties, continuous processes for soap-making have recently been developed. Here the saponification is carried out in special reaction columns, where lye and oil are intimately mixed, whereby the reaction velocity is increased many times. By means of completely automatic control devices the proportions of oil and lye are kept constant, thus avoiding both the use of an unnecessary and costly excess of lye, and an incomplete saponification reaction which may be harmful to the quality of the finished soap. The soap-making process is thus completely independent of the skill of the individual soapboiler. (See Figure III). The washing of the saponified mass for recovering the glycerol is also carried out continuously by means of centrifugal extractors. The washing with brine is carried out in counter current; this gives a high yield of glycerol aswell as a high concentration of glycerol in the spent lye. Both these factors affect the economy of the glycerol recovery to a considerable extent.

Also the fitting operation may be carried out continuously in modern plants. As the difference in specific gravity between the neat soap and the niger is small, the separation of the two soap phases is difficult. However, the hermetic separator as described above is especially suitable to deal with the problem in question and a complete separation of the phases formed in the fitting operation can be obtained.

The advantages obtained by a continuous soap-making process may be summarised as follows:

(a) The time necessary for producing a soapmass is reduced from nearly one week to one hour;

(b) a considerable reduction in space requirements and consequently in building costs;

(c) a very large saving in steam consumption;

(d) complete automatic control and consequently avoidance of formation of scrap; this involves considerable saving.

(ii) Soapmaking from Fatty Acids

As already mentioned, fatty acids obtained from soapstock as well as from other sources may be used as a raw material for soapmaking. Fatty acids may also be obtained directly from neutral fats by hydrolysis. The operations thus involved are first the production of fatty acids from low grade fats or acid oil, the purification of the fatty acids by vacuum distillation, and the production of soap from the fatty acids,

It is obvious that this sequence of operations gives the soapmaker a great liberty in his choice of raw material, because low grade raw material can be upgraded through the distillation of fatty acids. Another advantage is that working up of the "sweet water" obtained by hydrolysis of low grade fats is much easier than the recovery of glycerol from the spent lye containing salt.

On the other hand, both the investment costs, and the running costs for plants, which first split low quality fats into fatty acids and glycerol and then produce soap from the fatty acids are much higher than the costs for a plant which makes soap directly from neutral fat. The obvious reason is that the many different operations involved in the first method require considerable investment costs, and that the running costs, especially the steam consumption for the hydrolysis of the fat and the distillation of the fatty acids, are much higher than the costs involved in the direct manufacture of soap from neutral fats.

When fatty acids are used as a raw material for soapmaking, the soap-making plant itself is, of course, considerably simplified, as the washing for the recovery of glycerol is unnecessary. The plant thus only consists of the saponification column and possibly a centrifuge for separating the niger from the neat soap.

(iii) Finishing Operations in Soap-making

The soapmass obtained from batch or continuous plants contains maximum 68 per cent of soap and minimum 32 per cent of water. As the soap-boiling is made at approximately 100°C (212°F) the soapmass

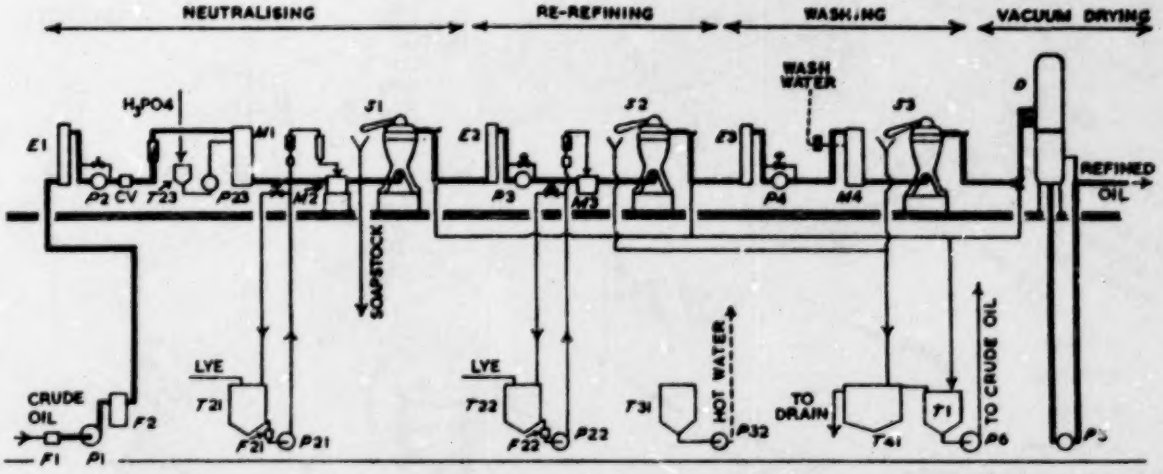
must be cooled down, and even then the water content is so high that the soap will easily dissolve.

In order to cool down the soapmass and to reduce the water content, dryers are used. Used nowadays are vacuum dryers where the soapmass is sprayed into small particles from which the water can easily evaporate. Laundry soaps are usually dried to a water content of about 35 per cent and toilet soaps to a water content of 28 per cent.

Laundry soaps may be cut and stamped immediately after drying, toilet soaps go through a number of treatments called milling, plodding and stamping. The purpose of these operations is to bring the solid soap mass into a state where the appearance of the finished tablet of soap is as pleasant to the eye as possible and where the soap does not dissolve too easily in water.

Modern vacuum driers are usually supplied with screw presses so that the dry soap is discharged as pellets. These pellets are treated in mills where perfumes, fattening agents, colouring agents, and so on are added. In order to obtain the desired physical properties of the soap, the mass obtained from the mills is treated in plodders, where a thorough mechanical treatment of the soap is carried out. Modern plodders usually work under vacuum in order to avoid any oxidation of the soap. The plodders are often built as double plodders, so that two mechanical treatments can be undertaken by the same machine. För very high grade toilet soap up to four plodding operations are usual. The soap leaves the last plodder as a bar of the desired dimension and is then cut into tablets and stamped. Finally, the tablets of soap are wrapped either by hand or by automatically working wrapping machines.

Figure I Continuous refining plant for fatty oils



F1.	Oil strainer	P23.	Proportioning pump for acid	F21, F22.	Lye strainers
P1.	Crude oil pump	M1.	Degumming mixer	P21, P22.	Lye pumps
F2.	Self-cleaning crude oil strainer	M2.	Neutralizing mixer	T31.	Water tank
E1, E2, E3.	Oil heaters	S1, S2, S3.	Hermetic separators	P32.	Process and flush water pump
P2, P3, P4.	Oil feed pumps	M3.	Re-refining mixer	T41.	Catch basin
CV.	Constant oil flow controller	M4.	Water washing mixer	T1.	Oil slop tank
T23.	Phosphoric acid tank	D.	Vacuum dryer tower	P6.	Oil slop pump
		T21, T22.	Lye tanks	P5.	Refined oil pump

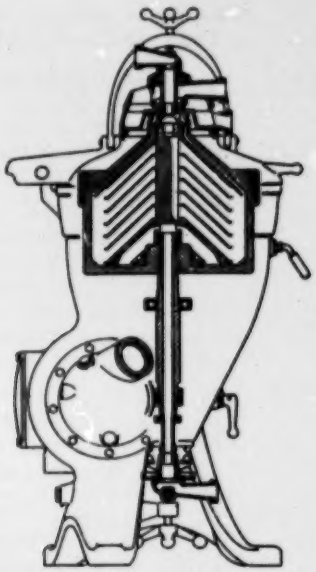


Figure II Hermetic centrifugal separator

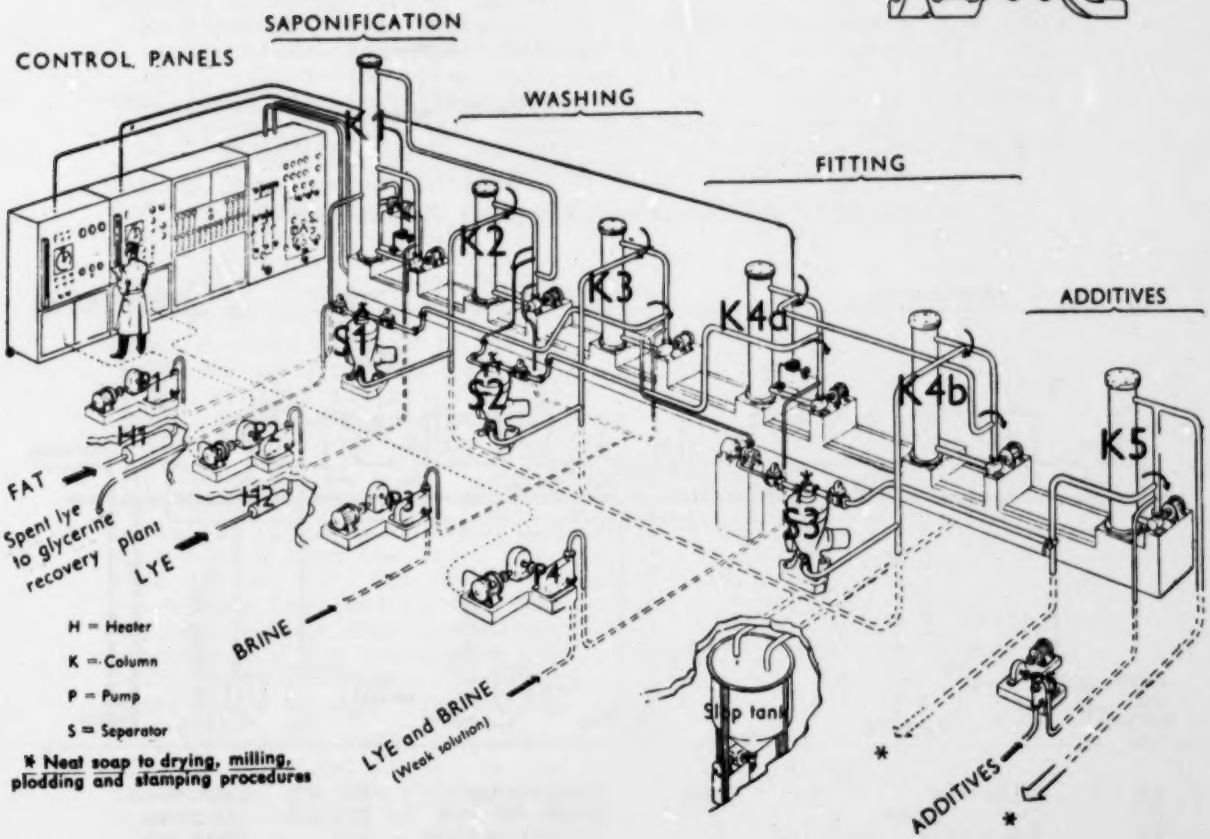


Figure III Continuous soap-making plant

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